MOUNT WASHINGTON OBSERVATORY, N.H., PROGRESS REPORT

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The Mount Washington Observatory (fig. 1) is going through its second year of operation. The unique history of this contemporary undertaking is outlined in a paper presented at the fourteenth annual meeting of the American Geophysical Union (Apr. 27, 1933) by R. S. Monahan and S. Pagliuca. (Transactions A.G.U., pp. 85–88.)

Meteorological observations and radio experimenting were started in October 1932 and have been carried on continuously for the past 14 months. The work, originally started for the purpose of cooperating with the second international polar year, is now embracing wider aims, particularly the resumption of the valuable series of observations carried on by the United States Signal Service from 1871 to 1887 the year around and for the following 5 years during the months of July–September only, following the famous Huntington-Hitchcock expedition of 1870–71.

With the increasing importance of a better knowledge of the upper air from the dynamic standpoint, the necessity of high-level observations is evident. Present means of upper-air observations are generally restricted to conditions favorable to the particular method used. In the case of mountain stations, once the local topographical influence on meteorological factors have been determined by means of auxiliary observations with airplanes, kites, balloons, etc., stations at the 2,000-meter level or higher would undoubtedly furnish invaluable data on the upper air. Mount Washington (1,915 m) favorably located in a region of frequent general storms, promises to yield data of a value commensurate with the necessary efforts and expenses.

The summit observatory is supplemented by two comparison stations one at 610 meters in Pinkham Notch and another at 795 meters at the base station of the Mount Washington Cog Railway; both equipped with standard and self-recording instruments.

During the months of June–September data on temperature, humidity, wind, precipitation, and cloudiness were gathered at the various huts of the Appalachian Mountain Club and Dartmouth Outing Club. The Greenleaf hut at about 1,250 meters on the west slopes of Mount Lafayette was particularly well equipped for complete observations.

Mr. S. P. Fergusson made his headquarters at the observatory last summer (1933) for his important aerological work by means of kites and airplane flights to determine the influence of the mountain on free air conditions. Many students and meteorologists have visited the observatory and availed themselves of the opportunity offered by the comfortable quarters, and expressed deep interest in the work.

The data obtained during the past 13 months of observations are now being tabulated by the observatory staff in accordance with international practice. It is expected that data and results obtained on Mount Washington will be published in full at an early date. It is also hoped that the prompt and regular availability of daily weather reports from the summit may be of some value to the forecaster.

Because of the peculiar difficulties experienced in obtaining current and special observations on Mount Washington, an outline of the methods used to secure reliable and continuous records may prove of value.

Mountain meteorology in this country deserves the best encouragement in the light of modern instrumental methods and theoretical trends, and Mount Washington, the oldest mountain station in the world, located on the stormiest peak ever studied continuously, is trusting to the cooperation of interested individuals and organizations to continue its contribution to meteorological and allied sciences.

To Dr. C. F. Brooks, director of the Blue Hill Observatory, Mr. Henry S. Shaw, Mr. S. P. Fergusson, the Meteorological Department of the Massachusetts Institute of Technology, and many other supporters the observatory staff: Joseph B. Dodge, director; Alexander A. McKenzie, summit radio operator; Salvatore Pagliuca, Wendell F. Stephenson, and Robert G. Stone, summit observers, are particularly indebted for having made possible the realization of this project.

Atmospheric pressure.—A mercurial barometer for direct reading, a mercurial barograph, and an aneroid barograph are used for atmospheric pressure measurement. The dynamic action of the wind and other causes inherent to the location of the station are frequently responsible for pronounced pressure oscillations which in some instances have reached the order of 0.2 inch on the recording instruments. These actions are being systematically studied in order to obtain quantitative data.

An attempt to determine the dynamic action of the wind on the mountain slopes was made last May with five well-equipped stations operating for 10 days on the west and east sides and intercommunicating by telephone and radiotelephone. The unfortunate lack of atmospheric action prevented obtaining the desired results, but simultaneous cloud observations and various other data were obtained. Plans are laid out for repeating this experiment very shortly, and perhaps more than once this winter, with the cooperation of several hardy volunteer observers.

Wind velocity.—The first real effort to obtain a continuous record of wind movement on Mount Washington was made last winter (1932–33), when the conventional type of cup anemometer was replaced with an electrically heated anemometer of special design, electrically connected to a weekly recorder. This instrument was installed on the observatory building, 8 feet above the roof ridge, and consisted of a stationary heater of the type commonly used in electric stoves and a cup-wheel rotor. Heat was applied during the long and frequent periods of rime and ice deposition (fig. 2). Early experiences proved the insufficiency of this design and the necessity of improvements. A new and improved anemometer was designed and built with the aid of the Permanent Science Fund of the American Academy of Arts and Sciences. The heater is totally enclosed except for a small air gap around the shaft. A double-circuit heating device of 700 watts maximum capacity permits the application of heat according to requirements. Other features are vacuum contacts for electrical recording, a special connection box, ball bearings, and an all-around sturdy and accurate mechanical construction. The velocity characteristic of the instrument is far from being ideal, but its chief purpose is to record with the accuracy of modern standardization methods, rime forming winds of superhurricane force.

FIGURE 1.—Mount Washington Observatory, after a storm. Members of staff inspecting heated anemometer, radio antenna, and instrument shelter. Cumulus clouds in the background are 1,000 feet below the summit. (Photo by W. H. Pote.)

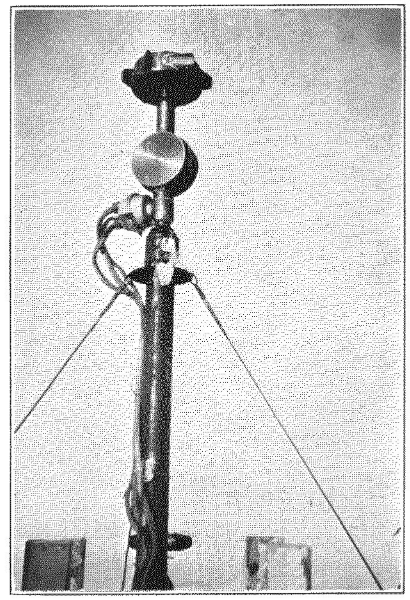

FIGURE 2.—Heated anemometer no. 2, with vacuum contacts and especially rugged construction.

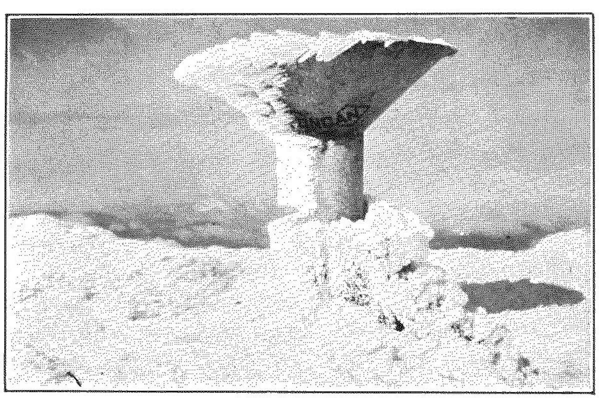

FIGURE 3.—Shield on 8-inch rain gage.

FIGURE 4.—All set for a night balloon run, Mount Washington Observatory.

FIGURE 5.—Rime from a single storm, October 1932, on pyrheliometer post. (Photo by Harold Orne.)

The anemometer was recently standardized at the United States Bureau of Standards and is to be exposed on a structure on top of the summit tank at an actual height of 10 meters above the geographical summit. The heat is supplied from the observatory 100 meters distant by means of lead-covered 20-conductor cables carrying 110 volts, direct current. A service shelter on the tank is electrically illuminated and connected by telephone to the observatory. Although the recording is obtained electrically at the observatory building, a frequent walk to the instrument is necessary, particularly under extreme conditions.

In connection with the electric heating of the wind-measuring instruments, and in order to assure a more accurate record of the duration of rime deposition, an ingenious device has been developed and called rime detector. It consists of a photoelectric cell which is acted upon by the light of an ordinary flashlight bulb, reflected by a small mirror exposed to the elements. As the rime starts forming on the mirror the reflected beam of light is weakened and the photoelectric cell, by means of an amplifier and a relay, acts as an alarm circuit. This circuit could be made to start automatically the power plant, but manual operation is preferable during the winter. A somewhat less reliable device, but with reverse action, is being built on the well-known principle of the thermo-hygrograph on the assumption that rime generally starts forming at below freezing temperature and 100 percent relative humidity.

Experiments are being conducted with a hot-air anemometer in order to develop a more economical means of heating the wind-measuring instruments, and a Pitot static tube is available for comparison readings under special conditions.

Wind direction.—The necessity of obtaining a reliable and continuous record of wind direction suggested the use of wind vanes of special design, electrically heated at the collar so as to be let free to rotate during rime-forming periods, and equipped for mechanical and electrical recording. In order to reduce rime accumulation the tail end of the vane only is being used, and various types of vanes are being tried. The over-all length is about 25 inches. Two of these vanes are being exposed, one at the end of the trestle and another on the summit tank, to avoid faulty wind-direction readings due to the influence of the summit buildings.

Precipitation.—Precipitation on Mount Washington generally occurs with high winds, which are influenced in direction and intensity by the topography of the summit and the presence of the summit buildings. Hence consistent results could only be obtained by exposing a number of gages at various points in order to average possible disturbing effects. Moreover, it was found necessary to equip the gages with shields in order to reduce the direct disturbing influence of the wind. After a series of experiments, in which the actual effect of the shield on the wind was studied by observing the orientation and length of rime feathers forming around it, a simple type of funnel-shaped shield with 45° angle of deviation and 30 inches upper diameter, was found satisfactory and standardized for all purposes (fig. 3). Four shielded gages located at cardinal points and one unshielded gage for comparison purposes are now being used. Wherever necessary, gages are slanted so as to make the upper surface parallel with the mountain slope. Collection is made twice a day, oftentime with considerable difficulties. Drifting snow seriously complicates the precipitation measurements. A close investigation of this problem is being conducted in order to determine as closely as possible the amount of drifting snow that is blown in the gages under different conditions of wind direction and velocity and the type of snow on the ground.

There seems to be hardly any relationship between the amount of snow caught in the gages and the amount of snow actually staying on the summit ground for any length of time. The strong westerly winds blow a huge amount of snow on to the eastern slopes and into the western ravines, where it stays until early summer. This drifting action makes it very difficult to determine even approximately the amount of snow on the ground. Drifts 10 to 15 feet high may alternate with almost bare spots. The amount of snow on the ground is given as the average of a number of depths obtained at points where drifting is absent or negligible, and special mention is made of size and frequency of drifts.

Rime deposition.—Lacking a standard expressing quantitatively the huge amount of rime deposition on the summit, only a record of duration and intensity of deposition is being kept with particular reference to the average rate of growth and maximum length of rime feathers on exposed objects. Feathers longer than 5 feet have been observed building against the wind (fig. 5).

For convenience we have agreed to call *rime* all depositions having a well-defined featherly appearance and resulting from cold fogs (or clouds) generally blown by westerly winds; and *rough frost* all despositions deriving from wet fogs (or clouds) at slightly below freezing temperature blown by winds of general southerly directions. Rough frost has the appearance of ice masses and has a much higher specific gravity than rime.

During the winter, fall, and spring months the station is more than 50 percent of the time in rime-forming fogs (or clouds). It therefore is favorably located for investigations on the important problem of ice formation on aircraft and an effort will be made this winter (1933–34) to establish a standard by which rime deposition can be recorded in a way similar to precipitation.

Air temperature.—Standard mercurial and spirit thermometers are used for recording current and extreme temperatures, and thermographs of the Bourdon tube type are used for continuous temperature records. These instruments with relatively little attention give satisfactory results under severe conditions.

Relative humidity.—The sling psychometer and hair hygrometer are being normally used for the measurement of relative humidity. The unsatisfactory results obtained from these two instruments at low temperature and rimy conditions suggested to the meteorological department of the Massachusetts Institute of Technology and the Blue Hill Observatory a concerted experimental attack on this problem. Simultaneous tests by means of a dew-point indicator, heated Assmann, sling psychrometer, hair hygrometer, sampling of air by means of previously exhausted bottles, Aitken counter, and Owens counter, have been made with the utmost care. These various methods show a more or less degree of consistency under somewhat favorable conditions. Dr. H. C. Willett has kindly agreed to discuss the preliminary results of these tests.

The development of a reliable and convenient instrument for the determination of the dew point and relative humidity at low temperature and rapidly variable conditions is a necessity in view of the developments of aviation, polar, and mountain meteorology.

Clouds observations.—Detailed cloud study is being made in accordance with international practice. Nephoscopic observations are being made regularly at least every 3 hours. The height of clouds is obtained by means of pilot balloons and occasionally by means of double nephoscope and double theodolite observations. A systematic study will be conducted by means of multiple nephoscope observations to determine the influence of the mountain on the height of medium and perhaps high clouds.

Aerologic observations.—Whenever conditions permit, hydrogen-inflated pilot balloons with 180 meters per minute ascensional rate are released and followed with a theodolite (fig. 4). A complication is being introduced in the computation of the ascensions where the initial elevation angle is negative due to downdraft effect. When enough double theodolite ascensions shall have been made, it will be possible to work out a scheme for calculating with a fair degree of accuracy the position of the balloon during the downward run.

So far more than 200 pilot balloon ascensions have been made. In one instance a balloon released 100 yards below the windward side of the summit followed nearly the same downward course of a balloon released from the summit.

Solar radiation.—Total solar and sky radiation on a horizontal surface is being recorded by means of an Eppley-type pyrheliometer bulb (fig. 5, right, top) connected to an Engelhard recorder. One of these bulbs was continuously exposed to the full severity of the elements last winter (1932–33), and was undamaged until overloaded by lightning last spring. Direct solar observations are made on clear days by means of a thermopile. All the solar apparatus was loaned and installed by the Eppley Laboratory, Inc., of Newport, R.I.

Aurora borealis.—The frequency and various developments of auroral displays are accurately recorded on star charts supplemented by theodolite measurements.

Optical phenomena.—Optical phenomena are accurately recorded in time and dimensions. Particular emphasis is given to coronae and halo measurements. Unusual visibility and time and character of sunrises and sunsets are also recorded.

Snow temperature.—Various tests of snow temperature at various depths have been made and correlated with variations in the air temperature.

Snow and rime sediments.—Samples of snow and rime sediments were taken and sent to the Massachusetts Institute of Technology for analysis.

Some meteorological data on Mount Washington and comparison stations for 1933

	Monthly mean temperature in degrees F.			Monthly precipitation in inches		
	Mount Washington	Pinkham	Concord, N.H.	Mount Washington	Pinkham	Concord, N.H.
January	12.6	24.2	30.8	4.59	3.03	1.95
February	7.0	20.8	27.6	5.58	3.75	3.27
March	9.2	22.7	31.1	6.90	7.80	5.23
April	25.4	36.9	43.0	9.45	8.07	6.36
May	37.0	50.7	57.8	3.66	3.33	2.44
June	46.1	59.2	66.9	5.36	2.87	1.25
July	49.6	60.6	69.1	4.63	6.36	3.25
August	49.7	59.3	67.4	10.13	7.76	6.01
September	42.2	54.2	60.9	5.04	2.74	4.54
October	29.7	42.0	48.4	4.64	6.77	4.90
November	12.2	26.4	33.1	5.69	1.89	1.50
December	5.0	14.6	20.0	4.11	4.97	2.76

	Average hourly wind movement in miles per hour		
	Mount Washington	Blue Hill	Portland
May	35.8	16.9	9.3
June	32.1	12.8	8.7
July	26.4	12.9	7.4
August	24.8	13.0	7.6
September	34.2	10.8	7.5
October	41.0	14.1	9.3
November	52.0	17.0	9.3
December	59.0	19.2	9.2

Maximum pressure, 24.20 inches (S.L. 30.75 inches) Oct. 21.
Minimum pressure, 22.51 inches (S.L. 28.74 inches) Mar. 9.
Maximum temperature, 71.0° F. June 28.
Minimum temperature −46.2° F. Dec. 29.
Maximum wind velocity, 164, miles per hour, recorded on Apr. 5.

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RECENT ADDITIONS

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